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Prof.dr.ir. C. Esveld
Professor in Railway Engineering

Annual Report

Chair for Railway engineering

Report period 1 September 1997 - 31 August 1998

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CONTENTS

Front page: Comparative measurement of dynamic rail displacement due to hammer induced impact load using an optical high speed deflectograph and conventional accelerometers.

1. GENERAL

1.1 Scope

High speed railways, durability and environmental issues are main themes which reflect also the research and development efforts of the railway engineering group of TU Delft in the past academic year. A major breakthrough in this respect was the implementation of the embedded rail principle to replace the classical ballast track system.

Concerning education, existing lectures in railway engineering were upgraded as a result of the general reprogramming of the curriculum from 4 years to 5 years. A lot of work was done in rewriting a new lecture book accompanying the base lecture in Railway Engineering.
The reprogramming caused a delaying effect resulting in a temporarily reduced number of new graduation students. Unfortunately, graduated students (M.Sc. level) are now in great demand in practice due to the start of major civil building projects involving railinfrastructure. This discrepancy is tackled by formulating interesting graduation projects and intensifying our enlisting attempts by information to third-year students, high school examinees and via Internet.

In the academic year 1 September 1997 - 31 August 1998 five graduate students finished their study in Railway engineering. A detailed description of their work is given in the chapter Education. As usual, students performed their graduate duties as part of a research project and in close cooperation with external companies or institutes active in the railway field. Some of the students held also a student-assistantship.

The research concentrates mainly on the development of mathematical models describing the dynamic behaviour. However, the excellent experimental facilities for the dynamic testing of rail track components at the in-house Laboratory of Road and Railway Engineering were used to their full capacity in order to meet the testing programme duties.
Staff members were participating in a number of research committees dealing with the optimisation of the technical design of existing and new rail track designs.

As before, an important part of the financing comes from contract research. Apart from this traditional source of income the group successfully raised money from educational services to third parties. In spite of these revenues the financial situation is worrisome a little due to the unfavourable split-up of the central means.

The understaffed situation, mentioned in the former annual report, has improved to some extent. It was possible to complete a financial plan enabling ir. A. P. de Man to start his Ph.D. study. Furthermore, ir V.L. Markine has joined the group per 1 January 1998 as a specialist in dynamic optimisation problems using large-scale software programmes. Finally dr.ir. A.W.M. Kok has joined the railway staff per 1 February 1998 on a half-time basis to continue his work on the development of small-scale dynamic models dedicated to certain classes of railway structure problems. Both also assist in instructing graduate students using these models.

Some smaller tasks, like managing literature and picture databases are planned to be carried out by student-assistants (not necessary graduate students)

1.2 Personnel railway engineering group

The following list shows the personnel active in railway engineering duties per 1 September 1998:

NAME	PHONE NUMBER	E-MAIL
Chair for railway engineering		
Prof.dr.ir. C. Esveld	+31 15 278 7122	esveld@ct.tudelft.nl
Secretariat (Section Road and Railroad Engineering)		
Mrs. J. Barnhoorn Mrs. I. Weijgertze Fax	+31 15 278 5066 +31 15 278 5066 +31 15 278 3443	j.barnhoorn@ct.tudelft.nl i.weijgertze@ct.tudelft.nl
Staff		
Dr.ir. A.W.M. Kok Ir. V.L. Markine Ir. P.B.L. Wiggenraad Ir. J. van 't Zand	+31 15 278 3206 +31 15 278 3206 +31 15 278 4916 +31 15 278 2304	a.kok@ct.tudelft.nl v.markine@ct.tudelft.nl p.wiggenraad@ct.tudelft.nl j.zand@ct.tudelft.nl
Ph.D.		
Ir. A.P. de Man Ir. S. Rasmussen Ir. A.S.J. Suiker	+31 15 278 4011 +31 15 278 2763 +31 15 278 2731	a.deman@ct.tudelft.nl s.rasmussen@ct.tudelft.nl a.suiker@ct.tudelft.nl

Furthermore, the following people are also involved in carrying out special tasks for Railway Engineering:

NAME	PHONE NUMBER	E-MAIL
Laboratory of Road and Railway engineering		
Ing. J. Moraal Mr. J.W. Bientjes Mr. J. Dorsman	+31 15 278 4012 +31 15 278 4028 +31 15 278 1515	j.moraal@ct.tudelft.nl j.bientjes@ct.tudelft.nl j.dorsman@ct.tudelft.nl
System Administrator		
Mr. R. Wibbelink	+31 15 278 8049	r.wibbelink@ct.tudelft.nl

2. EDUCATION

The following three courses were given by Railway Engineering in the three last years of the Civil engineering curriculum:

2.1 CTvk3710/Rbk part, (Traffic, Roads and Railways), 3d year, about 40 students.

- Introduction to railway engineering
- Basic principles of wheel/rail technique
- Train loads
- Track structures
- Maintenance and renewal
- Characteristic differences between road and railway

This introductory course on railway structures is comprised of 8 lecture hours and forms part of a more general course on traffic engineering. It includes a tutorial program and CAI exercises.

2.2 CTvb4870 (Railway Engineering), 4th year, eight students.

- Principle of railway guidance
- Layout
- Track design
- Track dynamics
- Thermal effects
- Track stability
- Rails
- Switches and crossings
- Inspection methods
- Maintenance and renewal

This basic course is comprised of 24 lecture hours and case studies and 40 hours computer aided training. A revised lecture book, in English, has been written and is undergoing some final alterations. However, the lectures are given in Dutch. 6 students and 2 guest students attended the lectures. Thanks to elaborate instructions all students got a sufficient result.

2.3 E58 (Traffic Engineering, Railway engineering part, old 4-years curriculum)

This course, dedicated to special rail related subjects, was given for the last time. Lecturers were:

- Dr.ir. A.W.M. Kok/prof.dr.ir. C. Esveld, Dynamics in Railway Engineering;
- prof.ir.C. Keizer, Interaction wheel/rail;
- ir. J. van 't Zand, Recent experiments in Railway Research;
- ir. P.N. Scheepmaker, Rational Railway Management;
- prof.dr.ir. C. Esveld, New measurement techniques of NS-RIB

The course was completed with an excursion to some rail track solutions in the HTM tram network. 11 students were examined orally. The resulting mark for each student was combined with the mark achieved in the road part of e58.

2.4 CTvb5870 (Railway Engineering, Capita Selecta), 5th year, about 5 students expected)

- Special subjects such as:
  - Current rail infrastructure projects
  - Advanced topics in track mechanics
  - Related vehicle technology
- Laboratory tests

This course is in preparation and will start for the first time in January 1999 (block 3).

2.5. Completed M.Sc. studies

In the academic year 1997-1998 the following five students have completed their master's thesis in Railway Engineering:

Student: **J.W. Diels**
Date:26 juni 1998
Subject:
Evaluation of existing and alternative track systems for Madrid Metro.
Description:
This graduation project was focused to answer Metro Madrid's question whether the existing track type (block track) should be retained or should be replaced by a possible better alternative. Six track types were selected to investigate their dynamic properties. Experiments were carried out to establish the value of some dynamic parameters. Then the mechanical behaviour of the track types was modelled and simulated using the program RAIL. The results showed no significant differences.

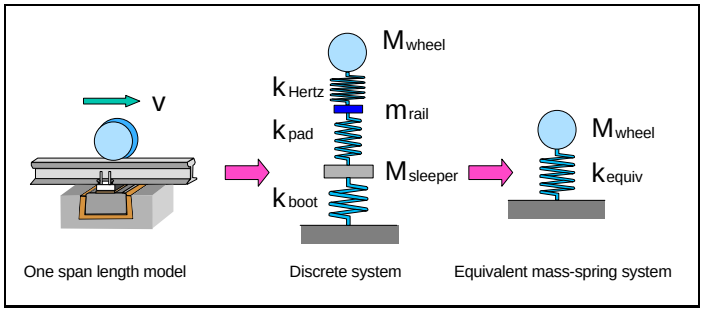

Figure1. Model simplification with equivalent dynamic behaviour

Student: **K.H. Oostermeijer**
Date: 26 juni 1998
Subject:
Dynamic behaviour of embedded rail construction (ERC) for the High Speed Line. (in Dutch)
Description:
In this graduation project a dynamic investigation was made to whether the embedded rail concept might be applied for in a high speed rail track. This ballastless track type is very attractive in terms of availability, durability and lasting track geometry but could develop unexpected dynamic effects at high speed. Based on measurements at embedded rail a number of simulations were carried of using the program RAIL to check this behaviour. which showed no negative effects at the anticipated speeds.

Figure 2. Hammer excitation testing of embedded rail construction

Student: **A.D. van der Vlugt**
Date: 26 June 1998
Subject:
Development of working regulations for rail track constructions (in Dutch)
Description:
The graduation project was concerned with working regulations used in building new rail infrastructure. This project was initiated following a request of Madrid Metro company to compare the current technique (block track) with alternative rail systems. Also a list of building defects, with their effect on service life, was produced. It was show that quality control during the design, work preparation and building is essential to prevent small and large building errors. The block track system was found to be suitable indefinitely within specific conditions.
Note: The managerial part of this project was carried out by gradient student A. Zoeteman of the Faculty of Technology, Policy and Management.

Figure 3. Picture of block track in Madrid Metro (photo AZ)

Student: **D.J. Vermeij**
Date: 28 August 1998
Subject:
Vehicle dynamic and passenger comfort related to track geometry in high speed track (in Dutch);
Description:
The effect of a chosen track geometry, with given vehicle properties and (high) speed, on the comfort experience of passengers, was investigated. First, the notion of passenger comfort was defined followed by a critical review of standards and criteria. Then a suitable geometric spatial model was developed, including vehicle and bogie behaviour (model ICE). To quantify the dynamics a simulation programme was written (SimHSL) to assess a number of typical geometric situations. As a case the route of the future Dutch High Speed Line was chosen.

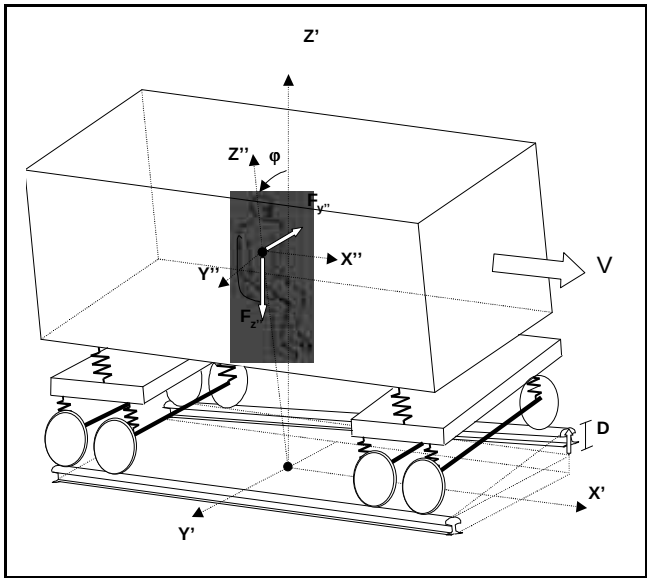

Figure 4. Vehicle model on curved track to determine passenger comfort

Student: **R.M. Siderius**
Date: 31 August 1998
Subject:
The feasibility of EPS as a subbase material in a rail structure.
Description:
This study looked at the possible use of the light-weight material EPS (Expanded PolyStyrene) in rail track structures, with the aim to prevent large settlements. A mathematical model was made of a slab track with an EPS-layer underneath. The mechanical behaviour was compared to a classical track on a sand base. A static consideration using the program GEOTRACK, revealed the minimal slab depth and the stress and deformation levels. Some basic dynamic properties were determined using the program RAIL. A number of applications were indicated. Finally, a global life-cycle cost calculation was made.

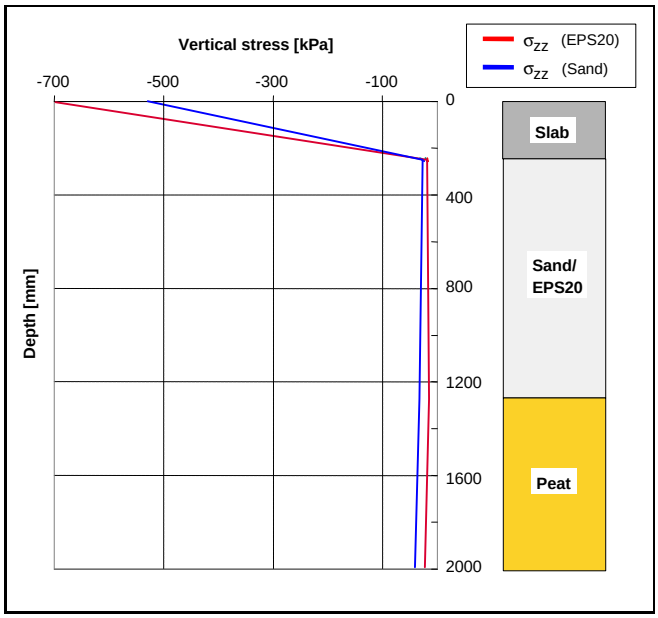

Figure 5. Vertical stress development of embedded rail track on either sand or EPS foundation

2.6 Current graduate studies

At the moment the following students are performing their graduate project:

H.T. Adema Development of a test methodology for embedded rail structures (Edimech) (in Dutch)
J.J. Velten Wave generation in overhead contact wires (in co-operation with Structural Mechanic group)

2.7 Current Ph.D. studies

At present the following three Ph.D. students in Railway Engineering are completing their respective doctoral thesis:

ir. A.S.J Suiker, Track deterioration under heavy axle loads (project HASLAST);
ir. A.P. de Man, Dynamic behaviour determination of railway track. (project DYNATRACK);
ir. S. Rasmussen, Application of High Speed Deflectograph in roads and railways.

3. RESEARCH

3.1 Theoretical research Railway Engineering

As a result of the recent appointment of dr. ir. Kok and ir. V. Markine (see Section 1) the theoretical part of the railway research activities has increased considerably. It is anticipated that mathematical modelling and programming in a user-friendly format is necessary to cover the needs in practice now and in the coming years. Moreover, this development is favourable for educational purposes, as demonstrated by the recent start-up of a rail track related computer practical work for Road and Railway Engineering students and for the coaching of gradient students.

3.2 Experimental Research Railway Engineering

The Road and Railway Research Laboratory has excellent facilities for the testing of large-scale and small-scale road and railway components. Moreover advanced loading and measuring methods are available or under development for in situ testing.
The current experimental railway research is mainly concerned with testing programs for fastenings systems (embedded rail included), concrete sleepers and slab track according to CEN (Comité Européen de Normalisation) standards. A number of current research programs will be summarized below.

4 RESEARCH PROJECTS

4.1 Experimental test programme on rail fastenings

The testing programme on railway track fastening systems according to CEN-standards is running very well and attracts attention all over. A second test rig was constructed to double the capacity and to meet the ICES -obligations. Apart from technical improvements to increase the automation level of the process, a number of recommendations were put forward about the CEN-standards themselves. Also, a new sub-programme was started to study the physical aspects of the embedded rail material itself, simulating the severe mechanical and environmental conditions in practice.

4.2 Silent train traffic project: fatigue tests on newly designed silent track structure

This research concerns the application of a special track design consisting of an embedded rail with an adapted profile to reduce noise emittance dramatically (5 dB(A)). The Railway group participates in the ICES-STV research consortium to carry out fatigue tests. Some important results were obtained.

4.3 Heavy axle load project

An interfaculty project group is working with three Ph.D.'s on the subject of wheel-rail interaction phenomena due to heavy axle loads. The railway part in this team is represented by ir. Akke Suiker, who started his Ph.D. study in 1995. The first part however deals with the analysis of high speed effects (see 4.4). The second part constitutes of the modelling of the deterioration process in a railway track due to a large number of train passages (heavy hail line) using the finite element package DIANA. In this academic year material parameters were determined during a stay at the University of Massachusetts, Faculty of Geotechnical Engineering, headed by Prof. Ernest. T. Selig.

4.4 Analysis of dynamic effects and deterioration process in railway track

This research subject forms the second part of the Ph.D study mentioned under 4.3. It deals with the analysis of dynamic effects in a railway track due to relatively high train speeds (high speed line) Also, the behaviour of ballast was modelled as a discrete particle structure to analyse the mechanical behaviour of individual ballast particles under high frequencies.

4.5 DYNATRACK: Easy measurement and assessment of dynamic track properties

Dynatrack is a Ph.D.-study with the objective to integrate dynamic track behaviour in the range 10-1500 Hz in three main phases: track system selection, track construction and track maintenance. It consists of two major tools:

- An in-situ/laboratory measurement method including a module to derive realistic (field) parameter values,

- A theoretical analysis method to simulate and optimise dynamic track behaviour in several well-defined representative situations.

In the academic year this technique has been employed successfully in several appropriate rail track projects.

4.6 HSD: High speed deflectograph for road or railway surfaces

The HSD is based on a number of laserdoppler sensors mounted on a heavy vehicle. The load will cause the road/rail surface to deflect and the velocity of that movement is picked up by the sensors. The fundamental measuring principle of the sensors is based on the Doppler effect. The PhD will focus on the link between measured velocities and deformations of the road and railway structure, the interpretation of the results, as well as developing relations between output of the HSD and existing measuring systems. After a period of optimising the measuring principle the first test runs on rail surfaces have been planned.

4.7 Development of software for analysis of track behaviour under moving trains

Two new models have been developed to assess the dynamic behaviour of the track more properly. The first model (called RAIL) improves the double beam model with discrete sleepers and some more enhancements. The second model (called SPOOR) improves the double beam model with a 2D finite element model of the supporting ballast bed, subgrade and formation.
A new development is the model DARTS, which integrates both vehicle and track dynamic properties.

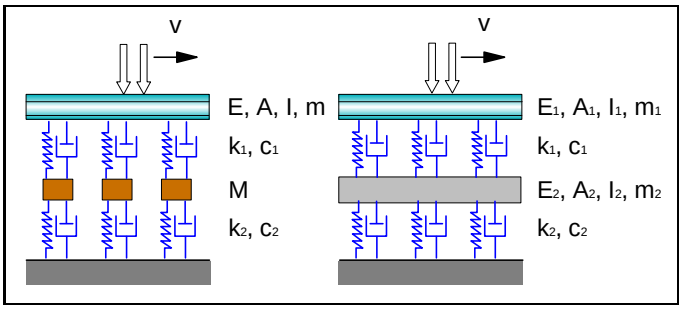

Figure 6. Example of the RAIL program model applied for discontinuous and continuous supported rail

4.8 Optimization of dynamic behaviour of an embedded railway structure

When the dynamic behavior of a railway structure has been analyzed, the next step is to optimize it. A modern numerical optimization technique was applied to determine optimal dynamic parameters of Embedded Rail Structure (ERS). Requirements for the optimal design of the ERS were related to the reduction of the wear of rails and wheels, as well as to the reduction of the level of the acoustic noise produced by a moving train. To obtain the optimal design, mechanical properties the ERS, such as stiffness and damping parameters of cork/polyurethane mixture were varied. The optimization problem was solved using a multipoint approximation method implemented in a IMOPT software package, which was externally coupled with the DARTS software.

4.9 Investigation of a dynamic phenomenon in an embedded rail structure

Appearance of Rayleigh waves in the Embedded Rail Structure (ERS) has been investigated. From the literature it is known that such waves can damage a railway structure as well as a train moving on it. The ERS has been modeled using RAIL and ANSYS software, which utilize the finite element formalism. The results have been obtained for a number of critical velocity cases. Additionally, an effect of gaps in a cork/polyurethane mixture layer on the dynamic behavior of the ERS has been investigated.

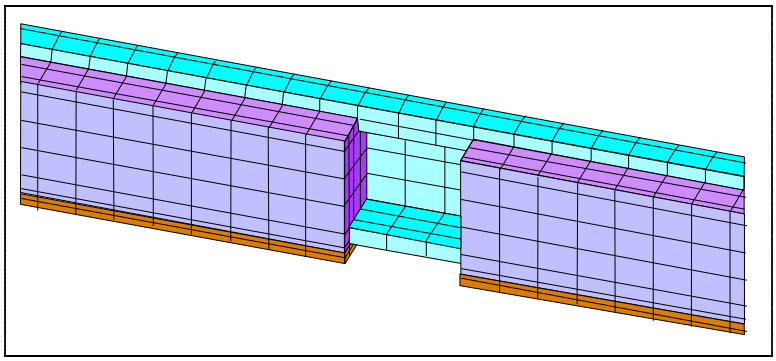

Figure 7. 3-D finite element model of ERS with gap (ANSYS)

4.10 Investigation and testing of embedded rail structures
A test series using the hammer excitation technique was carried out by the Railway group in-house at the Vossloh premises in Germany

4.11 Railpad Testing: Quick test method to obtain dynamical properties of rail pads.
On the request of Pandrol Rail Fastenings Limited a small test programme was carried out to determine the dynamic properties of a number of very soft rail pads using the Rail Pad Tester.

4.12 Water lubrication to reduce squealing noise of tram rails
To reduce squealing noise a simple but very effective means might be water lubrication. This possibility was studied by F. Marchetto , an Italian student, who fulfilled a training period on a Socrates scholarship for five months with the group. A number of empirical tests were carried out in an appropriate situation in the HTM network. Variables were lubrication spot, material type, speed, rail wear. The results will be published soon.

4.13 Study of the dynamic behaviour of high-speed track for HSL-South
This research was carried out as a master's thesis by K.H. Oostermeijer, commissioned by HSL Project Bureau (see Education, 2.5).

4.14 Evaluation of the Metro Madrid track system and investigations into alternatives
This research was carried out as a master's thesis by J.W. Diels, commissioned by Metro Madrid authorities. (see Education, 2.5).

4.15 Development of work instructions and construction standards for Madrid Metro
This research was carried out as a master's thesis by A.D. van der Vlugt, commissioned by Metro Madrid authorities. (see Education, 2.5).

4.16 Feasibility study on railway structures with a light-weight EPS sub-base.
This research was carried out as a master's thesis by R.M. Siderius in co-operation with Oranjewoud. (see Education, 2.5).

4.17 Vehicle dynamic and passenger comfort related to track geometry in high speed track
This research was carried out as a master's thesis by D.J. Vermeij, commissioned by Project Bureau HSL-South (see Education, 2.5).

4.18 Rational Rail Management.
This project concerns a feasibility study of the development of a general railway management system.

4.19 ECOTRACK project
This project, commissioned by ERRI, concerns the development of a decision and support system for the planning of maintenance and renewal of railway track.

5 PRESENT RESEARCH FOCUS

The central theme of the Railway Engineering group remains the study of the dynamic interaction between vehicle and track (including supporting structure) and, more specifically, between wheel and rail. This approach requires an interdisciplinary approach, as is the case already in the current HASLAST project.

The present trend of using the railway track system more intensively leads to higher demands regarding durability, minimizing maintenance, maximizing availability, safety- and environmental standards. It is clear by now that the traditional constructions and working methods are no longer capable to meet these demands. Therefore an innovative approach of the technical railway design should be aimed at.

The optimization of no-traditional structures like 'embedded rail', the revision of the rail section, and the applicability of materials like synthetic material, asphalt compositions light-weight foundations etc. should be (re)considered.
Furthermore a revaluation of design rules for rail track and the proceeding standards should be stimulated, taking into account the intrinsic dynamic nature of the railway system.
Also the improvement of the quality and accuracy of the building process by means of automated techniques is an important theme.

Though it seems premature, it is desired to assess the railway technical consequences of railway systems, based on magnetic levitation, including the technical matching with the existing systems. Recently, the Railway group is called upon by railway companies and -contractors, to incorporate in our research programme new research themes in addition to the existing traditional ones. These new areas concern the dynamic behaviour of catenaries, stray current problems, life-cycle costs, risk analysis, design of mixed bus/tramway slab track, etc. It is clear that in some cases external expertise of research groups within the TU Delft should be called in, possibly under co-ordination of the Railway Engineering group.

If this trend continues, the Railway Engineering group may develop eventually to a general research centre in the field of technical rail infrastructure.

6. MISCELLANEOUS

6.1 Co-ordination Committee Railway Engineering

This co-ordination committee Railway Engineering consists of representatives from railway companies, public service departments, CROW and TU Delft Railway Engineering (Esveld holds chairmanship). In this academic year the committee met four times. By now three working groups are active viz.:

- 'Track management/Decision support systems'
- 'Embedded rail'.
- 'Dynatrack'

6.2 CUR/COB project L400

The project committee L400 Vibrations is concerned with vibration problems in civil engineering structures, among them railways. The committee has started its activities under the chairmanship of Esveld from TU Delft Railway Engineering

6.3. Nomenclature Committee

The participation of the group in the CROW nomenclature committee, working group 4, 'Railway constructions' was reduced to a low level in the reported period, after an intensive start-up phase.

6.4 'Road Engineering Work Days'

In June 1998 the Railway Engineering group participated at the biannual gathering of experts in Soil, Road and Railroads to present their latest scientific findings in the field Railway Engineering. The contribution of the rail presentations is listed under Publications.

6.5. External contacts

In the reported academic year a frequent contact existed with the following companies, institutions and other organisations, who join an interest in railway infrastructure:
home: Bolith, C.R.O.W, CUR/COB, Edilon, ERRI, HTM, HRC, ICES, Nigtevegt, NS-RIB, NSTO, Oranjewoud, PHZI, Strukton Spoorwegbouw, NBM Rail, Volker Stevin Rail & Traffic.
abroad: Clouth, KU Leuven, Madrid Metro, NMBS, Pandrol, Phoenix, TU Graz, Vossloh.

6.6. Computer support

The computer facilities have been extended further. The Traffic Engineering Section is now represented on the Internet with their own website (http://vbk.ct.tudelft.nl/) with a link to Railway Engineering. Also an Intranet has been introduced for all internal information streams.

The following software programmes were developed or enhanced:

- RAIL, for dynamic analysis of a rail on a generalised elastic foundation, which can be run on normal PC's ;
- SPOOR, for dynamic analysis of a track on a multi-layer system;
- DYNATRACK, dynamic properties determination of track components;
- HASLAST, dealing with deterioration of the track due to repetitive loading (part of DIANA package);
- SIMHSL, determines passenger comfort in dependence of track geometry, vehicle properties and speed;
- Programming of small Matlab script files to improve the understanding basic static and dynamic track designs (for educational purposes).
- Furthermore, the programs CWERRI, LONGIN, SHARP CURVES and TURN have been tested or evaluated.

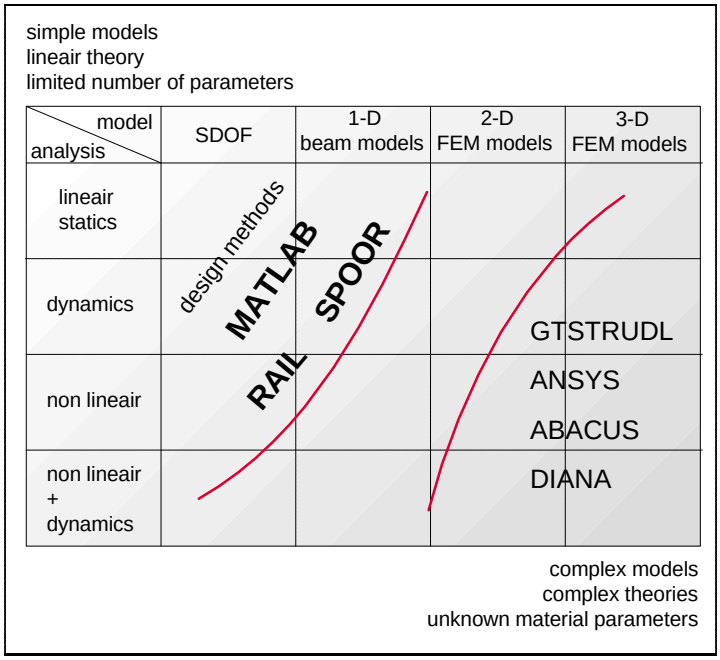

Figure 8. Diagram showing properties and relations of several mathematical

7. PUBLICATIONS

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6. Esveld, C., De Man, A.P., et.al., Interim feedback report Madrid Metro. Report 7-97-110-15, TUD/Rbk, 1997.09

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